Synopsis of

# Route optimization modeling and its applications

A Thesis

to be submitted by

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Under the Guidance of

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# OUTLINE OF THE PROPOSED TOPIC OF RESEARCH


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## Proposed Topic of Research

Route optimization modeling and its applications

## Objectives of the Proposed Research

1. To integrate different network or graph based optimization techniques into route optimization
2. To identify different application areas of the proposed integration pertaining to routing and scheduling
3. To understand the physical and geometrical representation aspects of routes.
4. To identify the best suitable algorithm(s) for few selected application areas of route optimization such as differentiated service networks, traffic routing, inventory routing, solid waste management etc.
5. To carryout economic evaluation of proposed algorithm for route optimization

## Background of the Proposed Research

Optimization is all about utilization of available resources at its best. It is the process of formulating a mathematical model of a real physical problem and with the help from this model try to find the best solution to the problem. The valuation of a solution is given by an objective function representing the aim of the problem and the feasibility is given by the regulation and limitation in the problem. Important for a good solution is that the model is the

representative for the real problem and the value of the solution measured by the objective is close to the optimal value for the model.

Today industrial production uses a lot of cooperative structures. One car contains about 20 000 different components from many suppliers from different cities and countries. This situation puts high demands on areas related to ordering, shipping and storage. So that started the discipline logistics. Any production can work when logistics doesn´t work properly. Transport and distribution of components and finished products is becoming a very important Part of the management and organization of production. There´s a known problem in route planning called, travelling salesman problem. Research proposes to describe such problem there is a set of points and objective is planning the route among these points. The route must intersect all points and a finish of the route is at the same point like a start of the route. For example a salesman goes from a town number one, he comes to all other towns but to every town comes just only once and there is the finish of his route back at the town number one. Certainly the route must be the shortest. There is the problem to find an optimum route among all points. This problem often arises in a number of logistical situations (for example transport components to factories, transportation of goods to the shops, check branches, distribution of mail, but also supply workplaces in assembly hall or Manufacturing plant etc.).

Problems with decision issues of yes/no type such as route optimization problems are often mathematically modeled as integer programs with binary variables which can be either 1 or 0. Most practical problems give rise to models whose sizes make them very hard to solve. They often belong to the set of so called nondeterministic polynomial (NP) time hard problems. There are no known algorithms for such problems which can solve them to optimality within a polynomial time, that is, the time needed for the optimal solution to be found grows faster than any power of the size of the problem. The beautiful theory of their corresponding linear formulations is not applicable and the methods for solving these cannot be used directly. One often has to settle with a near-optimal solution and to be able to find a good one in reasonable time demands the use of some suitable heuristics.

Transportation networks are complex, large-scale systems, and come in a variety of forms, such as road, rail, air, and waterway networks. Transportation networks provide the foundation for the functioning of our economies and societies through the movement of people, goods, and services. From an economic perspective, the supply in such network systems is represented by the underlying network topology and the cost characteristics

whereas the demand is represented by the users of the transportation system. An equilibrium occurs when the number of trips between an origin (e.g., residence/place of employment) and destination (place of employment/residence) equals the travel demand given by the market price, typically, represented by the travel time for the trips (Nagurney (2004)). The study of transportation networks and their efficient management dates to ancient times. It is known, for example, that Romans imposed controls over chariot traffic during different times of day in order to deal with the congestion (Banister and Button (1993)).

Another approach widely used for solving routing problem is the use of heuristics. Many of these are some sort of genetic algorithms which are characterized by the use of randomness to modify a given solution over and over again. Bent and Van Hentenryck(2001) uses a hybrid algorithm with simulated annealing in combination with a large neighborhood search to solve a VRPTW. In this problem they first minimize the number of vehicle needed, all identical, and then minimize the travel cost given this fleet of vehicles. Thanghiah uses a method based on something he calls genetic sectoring which by genetic algorithms adaptively searches for sector rays that partitions the customers into sectors served by each vehicle.

## Literature Review of Research Topic

Vehicle routing and scheduling problems have been extensively examined in the literature (Bodin et al., 1983). In fact, routing and scheduling of vehicles is deemed to be a major success story, mainly because of efficient modeling and implementation and the close connection between theory and practice (Assad, 1988). Unlike the rail industry, which is seriously looking forward to enhancing its operational efficiency and rationalizing its planning decisions further (Assad, 1980)

Appelgren (1971) utilized integer programming methods to solve a vessel scheduling problem. The problem was to determine an optimal sequence of cargoes to each vessel in a given fleet during a specified time period.

Yan and Tseng (1999) mentioned that the establishment of timetables and crew scheduling always affect the efficiency. They attempted to develop an integrated model using solution algorithm to help carriers simultaneously decide fleet routes and suitable schedules. In order to manage the interrelationships between trip demand and flight supply, they applied a time-space network model to formulate the movements of aircraft and passenger flows. Mathematically, the model was formulated as a special multiple commodity network flow problem. They developed a Lagrangian-based algorithm to efficiently solve the problem.

Recently Harris et al. (2014) proposed a hybrid multi objective approach for green logistics modeling. They used lagrangian relaxation (LR) approach. The multi objective evolutionary algorithm (MOEA) is used at level1 to determine, which facilities to open and the LR solved the generalized assignment (GAP) problem. Ozgur baskin (2014) discussed the capabilities of various algorithms to solve continuous network design problem (CNDP). In his study he performed harmony search (HS), artificial bee colony (ABC) and differential evolution algorithm. He found advantage of differential evolution algorithm over HS and ABC algorithm.

A Study on vehicle routing with time window has been done by Desrochers (1988). Suorsey and Ballard (1984) discretize the time window and solve linear program. Derrpsiers, Sauve and Soumis (1985) study Lagrangian relaxation and network relaxation, which is obtained by removing the scheduling constraints.

Steve H.K. Lee (1995) conducted research for route optimization model for strike aircraft. He designed a model and implemented to construct a "flyable" least risk route for strike aircraft from takeoff to target using lagrangian relaxation algorithm. Automatic route optimization model for aircraft (AROMA) has been implemented in C++.

Anderson and Lindroth in (2005) proposed a method combining column generation with greedy heuristics to solve route optimization for school transportation. Myles et al. (1995) used route optimization and integrated authentication to design and implement a new mobile host protocol called internet mobile host protocol (IMHP).

Wang and Chen (2001) did a research on air freight network optimization. The research looked for the optimal route in the hub and spok network via mathematical programming. Fungenshuh et al (2010) conducted research on mixed integer nonlinear problems in transportation applications. They presented research on two transportation applications (a) railway freight on one side and (b) natural gas on the other. The research was focused approximation of nonlinear part into linear way.

Laporte et al. (1992) consider a multiple vehicle routing problem with stochastic travel times and service times. Each vehicle has a targeted time to complete the route. They proposed a chance constrained model and a stochastic programming model, and suggest branch and cut algorithms to solve moderate-size problems. Kenyon and Morton (2003) mainly focus on the length of the longest route traveled by multiple vehicles and develop two versions of the model by minimizing the expected completion time or maximizing the probability of completion within a given deadline, and finally solve the model by branch-and-

cut scheme.

Sharma et al.(2009) studied on robust transportation network design problem. They used pareto optimal multi objective optimization model developed on the basis of revised fast and elitist nondominated sorting genetic algorithm. Beker et al. (2012) worked on shortest path algorithms as a tool for inner transportation optimization.

Agra et al. (2012), and Lee et al. (2012) formulate the vehicle routing problem with time windows, and propose different approaches, for example, Dantzig-Wolfe decomposition approach and dynamic programming, to solve the problem.

From an economic perspective, some of the earliest contributions to the subject date to Kohl (1841) and to Pigou (1920), who considered a two-node, two-link transportation network, identified congestion as a problem, and recognized that distinct behavioral concepts regarding route selection may prevail ( Knight (1924)).The formal study of transportation networks has challenged transportation scientists, economists, operations researchers, engineers, and physicists for reasons, including: the size and scope of the systems involved; the behavior of the users of the network which may vary according to the application setting, thereby leading to different optimality/equilibrium concepts; distinct classes of users may perceive the cost of utilizing the network in an individual fashion, and congestion, which is playing an increasing role in numerous transportation networks.

## Gap in Existing Research

The purpose of this research is to look at a development of the core in the application of the construction of routes. More intelligent approach is needed to be built into the system so that it can handle the properties like a limited vehicle fleet composed of different vehicle type with different specifications. The thesis proposes to include a mathematical model formulation and algorithm construction for three case studies based on public transportation, inventory routing, differentiated service networks etc. however theme of the case study will be decided after a detailed literature review study.

- The existing literature on routing optimization suggests that various problems can be solved using various methods such as integer programming, dynamic programming, lagrangian method, genetic algorithm and ant colony optimization etc. Generally these methods are used for optimizing the cost and time associate with the problem to get optimum combination of route and vehicle. Very less data shows the research done

for forecasting the route pattern to optimize the problem and applicable to real life problem.

- A very limited study is done on how different key figures such as number of vehicles, distance driven and maximum waiting times, changes when modifying the parameters and the rules in the problems.
- The existing literature review indicates that various algorithms have been developed for routing optimization for various applications but most of the researches done for transportation and traffics problem only.
- There is a lot of scope of routing optimization in modeling a route pattern and forecasting the number of vehicles.
- Several Bio-inspired algorithms have not been explored to solve the route optimization models for example Bio-geographic Based optimization algorithm (BBO) has not been used by the researchers so far whereas Genetic algorithm has been used significantly. The proposed study will focus on comparing different bio-inspired algorithms applicable to selected cases and to find a more efficient and suitable algorithm.

## Methodology

Based on the objectives set for the present study and the background work reported in literature with their limitations, the methodology of the present study is proposed as follows:

### Phase 1: Literature Survey

A detailed literature survey will be carried out to understand the routing optimization and its mathematical models. This literature survey is proposed to be made in the direction of serving our research objectives pertaining to routing, scheduling, identifying suitable algorithm and to identify the suitable problems for case study. Continuous literature survey will be carried out to collect the information required at various stages of the proposed research. The source of this literature survey will be books, conference proceedings, web articles and research papers published in various peer reviewed e-journals.

**Phase 2: Selection of application areas and cases**

In the second phase, the research work is proposed to be focused on selection of application areas based on review of literature. The selected application areas are proposed to be discussed through three selected cases.

**Phase 3: Mathematical Modeling**

A mathematical model will be formulated on the basis of proposed algorithm. It will be a mathematical interpretation of routing parameters such as cost, time, number of vehicles and forecasting etc. Using the mathematical model, parametric study and sensitivity analysis will be carried out to get optimum value of parameters will be found out.

**Phase 4: Selection of Algorithm/Methodology**

In this phase, comparison between different bio-inspired algorithms applicable to selected cases will be done and it is proposed to find a more efficient and suitable algorithm.

**Phase 5: Mathematical Analysis and Findings**

After preparing mathematical models of the selected cases, the selected suitable algorithm is proposed to be implemented for finding the results. In this phase, results are proposed to be analyzed as well. The economic evaluation of these results are also proposed to be done in this phase.

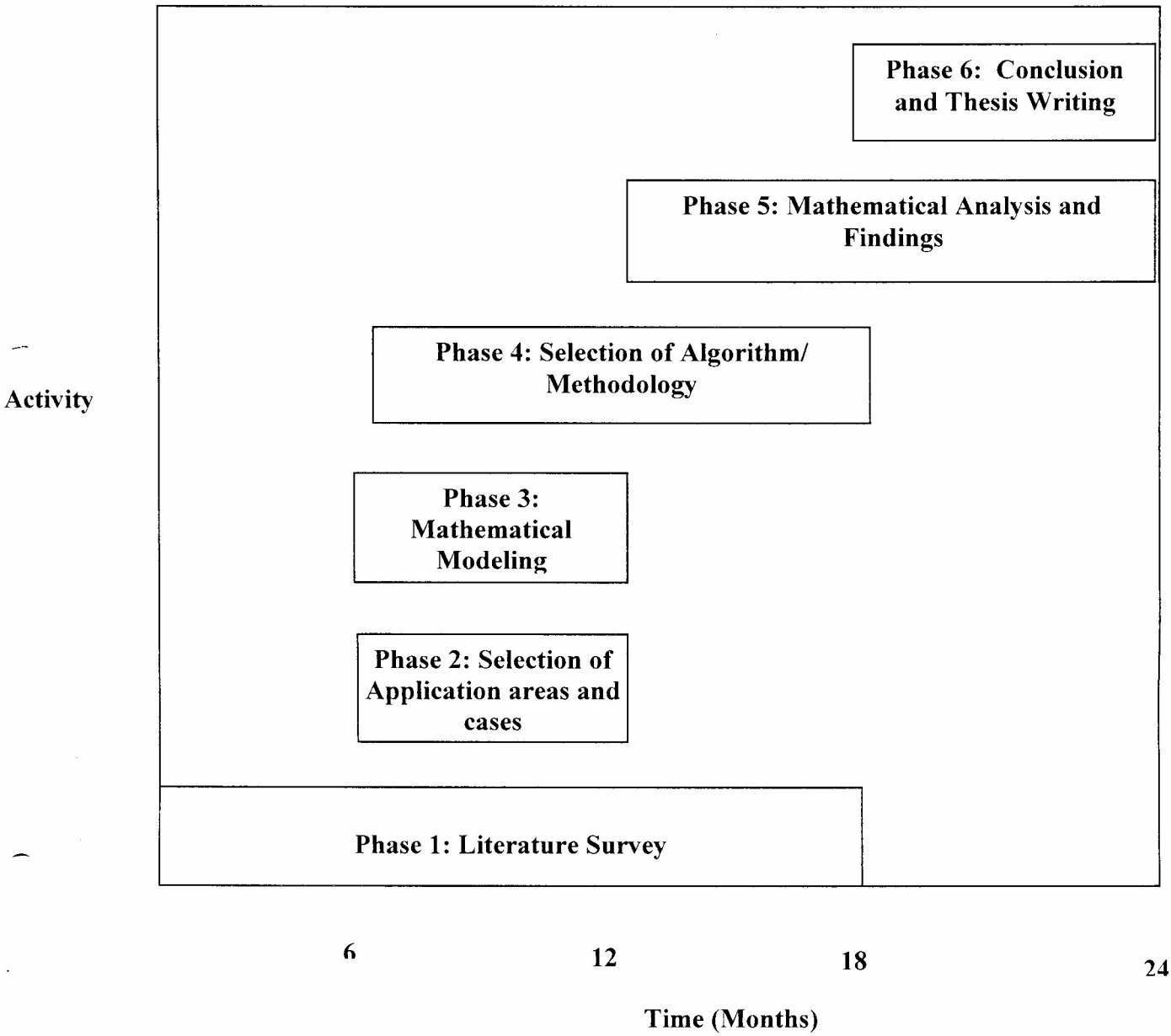
**Phase 6: Conclusion and Thesis writing**

In this phase, final conclusion of the proposed thesis is to be drawn pertaining to the research objectives. Thesis writing work is proposed to be done in this phase.

## Work Plan

The work-plan for the above-mentioned seven activities is shown in figure 1.

**Figure 1: WORK PLAN**



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